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ABSTRACT

Results of a survey of five Oxfordshire comprehensive schools regarding attitudes and opinions related to mathematics are reported. Three short scales dealing with perceptions about the use of mathematics, the teacher, and student interest were formed by adding the ratings of the items dealing with each category and averaging over the items in each scale. The sample consisted of 644 pupils who ranged from the top 25% to 50% of their year group. The investigation presents results of separate cluster analyses for boys and girls. Interviews with 44 pupils are reviewed for general impressions. The results of this research indicate that pupils generally view mathematics as a useful subject. Sex differences on items which were intended to be predictive of choice of mathematics for study were in favor of males. Students' responses suggest strongly that the best way to increase interest in the subject is to help them to understand it. (MP)

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UNIVERSITY OF OXFORD DEPARTMENT OF EDUCATIONAL STUDIES

Mathematics and 14-year-olds

Stephanie Kiryluk and John K. Backhouse

January 1981

Abstract

Results of a survey in 5 Oxfordshire comprenensive schools are reported under the headings of Interest, Use, Teacher, Sex differences and Influence of earlier schools. Results of separate cluster analyses for boys and girls are given. Pupils' attitudes to mathematics were explored by interview.

Pupils generally viewed mathematics as a useful subject. Sex differences on items which were intended to be predictive of choice of mathematics for study in the sixth form were in favour of boys. Pupils' responses suggest strongly that the best way to increase interest in the subject is to help them to understand it.

Introduction

Work on an SSRC funded project entitled "Choice of mathematics for study at school and university" led us to carry out a survey of third-year pupils in five Oxfordshire comprehensive schools in the summer term of 1979. The schools chosen had been established as comprehensives for a substantial length of time, so that any problems caused by recent reorganization were avoided.

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Since we were primarily concerned with future A level choice, the sample was limited to those pupils who, in the opinion of the school, were potentially capable of at least one A level in any subject. In effect, our sample of 644 pupils ranged from the top 25% to 50% of the year group, depending upon the size and intake of the school and the setting arrangements within the third year. A substantial amount of information was collected by both questionnaire and interview, with the intention of continuing the study when the pupils reach the sixth form. In this article we report mainly on pupils' responses to one of the questionnaires and the interviews; full details of the instruments used will be found in Backhouse et al. (1980). The questionnaire with which we shall be concerned consisted mainly of statements which pupils were asked to rate on a five-point scale of 1 (Disagree) to 5 (Agree); examples of those will be found below. What we hope to do in this article is to build up a picture of mathematics as seen by these third-form pupils.

Three scales

We have found it helpful to bring together a number of items into three short scales. These were formed after we had carried out a factor analysis[1] by taking the items with the highest loadings on the first three factors extracted but they are not intended to represent factor scores. The items forming the scales, together with their loadings on the respective factors are as follows:

Factor 1	loading
"Maths is useful for everyday life"	0.54
"Maths helps me with other subjects"	0.53
"I need maths to get a job"	0.63
"I think I'll use maths in my future job"	0.63
"Maths is useful for many jobs"	0.59

Factor 2	loading
"I could do better in maths if the teacher explained things more clearly"	-0.70
"I like my maths teacher"	0.71
"My teacher explains maths well"	0.87

Factor 3	loading
"On the whole I find maths much more interesting than/ more interesting than/ about the same as/ less interesting than/ much less interesting than other subjects."	-0.74
"I look forward to maths lessons"	0.70
"I find maths interesting"	0.71
"I am often bored in maths"	-0.56

It is clear that these three factors are connected with (1) the Use of mathematics, (2) the Teacher of mathematics, and (3) Interest in mathematics. Scales were formed by adding the ratings on the items concerned and averaging over the items in the scale; these scales will be referred to as Use, Teacher and Interest.

Interest

The differences between means scores for schools on the Interest scale were neither large nor statistically significant. It will not be a matter of surprise that there was considerable variation in the mean scores of different sets ($F_{21,595} = 3.96$, $p = 0.000$, from one-way analysis of variance). As might be expected, those in the top sets tended to score higher but there was considerable variation from set to set: for top sets the means ranged from 2.73 to 3.72, while the corresponding figures for second sets were 2.65 and 3.30. It is clear, then, that even top sets can fail to be interested in mathematics.

The writer selected three top sets with high mean Interest scores and analysed their responses to two items on an open-ended questionnaire. The items were

"Maths is interesting when ..." and "Maths is boring when ...". Comparatively few responses mentioned particular branches of mathematics and some topics, such as graphs, were viewed in contrary ways. What was clear was that in each set the most frequent response was that mathematics was interesting when the class were doing something new: the proportions varied from about a third to a half of the set. Next, rather more than a quarter of the pupils in these sets mentioned that the subject was interesting when they understood the topic or, in a very few cases, they knew how to do the work set. For the rest, there was considerable variation between sets. In one set nearly a third wanted the work to be challenging, for instance, work which "needs thinking about but isn't too difficult". The need for work to be neither too easy nor too hard appeared in all the sets but the response rate could easily have been affected by just having had work set which was found too hard or too easy. In all, the writer gained the impression that the pupils wanted their minds to be "stretched" with new work (repetition and revision were unpopular) which had challenge but which they would master. This confirms the view of Skemp (1971, 134) that mental growth provides intrinsic motivation. There were a few mentions of interest in applications of mathematics (e.g. to the general election of 1979), one to puzzles and another to discovery; what is not clear is how much the three sets had experienced these in mathematics lessons.

Use

There was some difference between school means on the Use scale ($F_{4,601} = 3.11$, $p = 0.015$, from one-way analysis of variance), ranging from 3.99 to 4.30. Analysing the items separately, "I need maths to get a job" was the only statement to reach significance ($F_{4,615} = 3.94$, $p = 0.004$); the lowest mean was for a rural school (3.93) and the highest from a school in the Oxford area (4.45). Three other items did not reach significance either between schools or between the 22 sets across schools: "Maths is useful for everyday life", "I think I'll use maths in my future job", and "Maths is useful for many jobs". The remaining item, "Maths helps me in

other subjects" varied greatly from set to set ($F_{21,601} = 3.02$, $p = 0.000$) ranging between 3.20 and 4.44 with the top set having the highest mean in each school. This last result is not surprising since those in the top sets are more likely to have mastered the mathematics they have learned and so would be in a better position to apply it to other subjects.

Isaacson and Freeman (1980) have pointed out that some one may recognise that mathematics may have an important place in the curriculum without it being personally important. Referring to the items in their order when the scale was first described, the first and last statements are general and had means 4.39 and 4.65, while the personal statements 2 to 4 had means 3.80, 4.30 and 3.90. The inter-correlations within the two groups ranged from 0.290 to 0.486 while those between items from different groups ranges from 0.311 to 0.387. These figures may reflect the distinction made by Isaacson and Freeman.

Teacher

The inter-correlations on this scale were all higher than the highest on the Use scale and ranged from 0.486 to 0.740. There was another item mentioning the teacher, "I ask the teacher when I don't understand" and this had a correlation of 0.273 and below with the items on the scale. There was some variation between school means on this scale (3.10 to 3.53, $F_{4,600} = 9.45$, $p = 0.000$, from one-way analysis of variance) but the variation is attributable to differences between the 22 sets. It is worth mentioning that top sets did not necessarily have high mean scores: these varied from 2.61 to 3.74, while the means of all other sets varied from 2.66 to 3.72.

Kiryluk (1980) has given the flavour of the pupils' responses to the open-ended items which mention the teacher, including a large number of quotations. Here we report responses from the three top sets mentioned earlier to "A good maths teacher is one who ...". The salient result is that 63% of the group used the verb 'explain'

and, with similar responses, 76% were making the point that good explanations are the mark of a good teacher of mathematics. Some went further, mentioning that the teacher should explain clearly or carefully, or expressed the view that the teacher should be prepared to go over something several times - or until the pupils understood. The next largest proportion , 33% rising to 36% with similar responses, mentioned that a good mathematics teacher would give help when it was needed. Sometimes linked with this, but more often separately, was the concern expressed by 26% that the teacher's manner of responding mattered: "Doesn't shout and complain if questions are answered incorrectly", "Does not get angry quickly or is not impatiant" and "... does not moan at you when you ask questions you should have remembered the answer to". Some 18%, evenly spread through the sets, mentioned class control in some form or another and 10% or less mentioned each of humour, interest, understanding the pupil's problem, and pace. We are inclined to think that the pupils' responded with what was "on top of their minds", so that class control, which one would expect to be good in top sets, would be less of a current concern to them than the need to understand, which would be felt in lesson after lesson. Interest and humour did not come into the responses from one set, while both appeared quite prominently in those from another which had slightly lower mean score (3.60 and 3.40) on the Interest scale; this would be in line with the view that pupils are more likely to write about unsatisfied needs.

Sex differences

It was not one of the primary aims of the project to investigate differences between the sexes but it is evident from the ratio of boys to girls taking A level mathematics that differences between boys and girls must be considered. Items about school subjects were included in a questionnaire completed by the pupils before they were told of our interest in mathematics. On a five point scale 1 (Bad at) to 5 (Good at), the boys' and girls' means were respectively 3.87 and 3.53 ($t = 4.61$, $p = 0.000$)[2] and on another scale 1 (Dislike) to 5 (Like) the means were 3.89 and

3.55 (t = 3.71, p = 0.000). Although there were more girls than boys in the sample, 72 boys and 50 girls responded with 5 (Good at) and 103 boys and 84 girls with 5 (Like). It is clear that there is already in the summer of the third year an emergent difference between the sexes' attitudes to mathematics. Some further aspects were explored in the questionnaire with which we have chiefly been concerned.

Referring to the scales introduced earlier, the difference on Interest did not reach significance at the 5% level although there were mean differences of 0.19 and 0.26 on the item comparing interest in mathematics with other subjects (t= -2.54, p = 0.011) and "I find maths interesting" (t = 2.63, p = 0.009). On the other hand there was a statistically significant mean difference of 0.26 on Use (t = 4.76, p = 0.000), with mean differences on the individual items (see the original description of the scale) of 0.17, 0.30, 0.25, 0.37, 0.19 (t = 2.54, 3.52, 3.13, 3.93, 3.43, p = 0.011, 0.000, 0.002, 0.000, 0.001). On all these items boys viewed mathematics as more useful than girls and the larger differences relate to the items referring to personal use of mathematics as Isaacson and Freeman (1980) were suggesting.

The responses to "I like my maths teacher" from the boys were less favourable to the teacher than those from the girls (means 3.04, 3.34, t = -2.59, p = 0.010). Then there were several items not included in the scales which yielded differences of some interest; the boys' means are given first:

"I like a difficult problem in maths"

3.14, 2.61, t = 5.00, p = 0.000.

"I ask the teacher when I don't understand"

4.00, 4.20, t =-2.36, p = 0.018.

"Maths is a boys' subject"

1.42, 1.24, t = 2.64, p = 0.009.

"I often get stuck in maths"

3.02, 3.30, t =-3.00, p = 0.003.

"I like to discover things in maths"

4.01, 3.66, t = 3.91, p = 0.000.

"I get worried if I can't do my maths"

2.98, 3.29, t = -2.93, p = 0.004.

"I find maths difficult"

2.70, 3.01, t = -3.21, p = 0.001.

The very low means for "Maths is a boys' subject" indicate a strong disagreement with the statement by both sexes; it is ironic that the girls show a greater disagreement while other evidence points in the opposite direction. The other six items might all be taken to indicate that girls have less self-confidence in their ability at mathematics than boys have. This interpretation would be in line with the view expressed by Preece (1979).

Influences of junior/middle schools

Since pupils learn mathematics for 6 to 8 years before reaching the comprehensive school, it is to be expected that their previous schools will have a lasting effect on the attitudes to mathematics of many children. We included one item with this in mind: "In junior/middle school I found maths very difficult/difficult/all right/easy/very easy". We are aware that a single item, particularly a retrospective one, has low reliability but over a large number of people results may nevertheless be instructive. Only 7 pupils responded "very difficult" and so these were combined with those who responded "difficult", forming a four point scale 2 (Difficult) to 5 (Very easy). With four groups in place of two, a one-way analysis of variance took the place of the t-test used in the last section. We report on items significant at the 0.1% level for which, with one exception, the means increase (or decrease) strictly with the points of the scale. Three items were the first three on the Interest scale (see its original description) with means of the two extreme groups respectively 3.29, 2.62; 2.29, 3.01; 3.13, 4.01. Two items were on the Use scale - the second and fourth in its original description - with means of the extreme groups 3.50, 4.05; 3.59, 4.19. Other items, with means of the extreme groups were:

"I like a difficult problem in maths"	2.21, 3.50,
"The maths we do is too easy"	1.56, 2.23.
"Maths worries me more than other subjects"[4]	3.12, 2.33.
"I often get stuck in maths"	3.63, 2.66.
"I find maths difficult"	3.40, 2.29.

It would be a mistake to pursue analysis of this item on the perceived difficulty of mathematics in the junior/middle school too far, however it would appear that in many cases attitudes to mathematics are largely formed in the junior/middle schools. This is not to say that the comprehensive school is uninfluential but rather that both it and the preceding schools are important in this respect.

Groups of pupils

We are planning to follow up the pupils in the sample to find out what choices of sixth form subject they make. We were therefore interested to see whether the pupils could be grouped in ways that would enable us to make predictions about choice of mathematics. One method we have used has been cluster analysis.[5] The boys' and girls' data were analysed separately; seven groups of boys and four groups of girls were identified. Table 1 gives the mean scores on the Interest, Use and Teacher scales for the eleven groups. Since the girls' analysis produced fewer groups than the boys', it is easier to discuss the former first.

Table 1

Mean scores of cluster analysis groups on Interest, Use and Teacher scales.

Boys

Group	n	Interest	Use	Teacher
1	35	2.54	4.10	3.30
2	53	3.17	4.39	3.58
3	25	3.07	4.60	2.89
4	71	4.18	4.56	3.51
5	22	3.01	4.68	2.57
6	14	1.73	3.13	2.79
7	24	1.90	4.35	2.75
All	244	3.14	4.37	3.23

Girls

1	100	3.14	4.47	3.47
2	60	1.69	3.79	2.79
3	62	2.69	3.37	3.45
4	67	4.22	4.61	3.58
All	289	2.99	4.12	3.35

Note: the total size of all eleven groups is less than 644 because the CLUSTAN1C analysis does not permit missing data.

Girls' groups

Group 4 had the highest mean on each of the three scales and can be said to have had a generally favourable attitude to mathematics. In contrast, Group 2 had a very low mean on the Interest scale, the lowest on the Teacher scale and their mean on the Use scale was below average; in all they appeared to have a generally unfavourable attitude to the subject. Groups 1 and 3 fell in between the others, with the exception that Group 3 had the lowest mean on the Use scale; this group is further distinguished from Group 1 by a lower mean on the Interest scale and by a low mean on the item "I like a difficult problem in maths", so it seems that overall they had a less favourable attitude to mathematics than Group 1.

Boys' groups

Group 4 had a generally favourable attitude to mathematics with high mean scores on all three scales. Groups 6 and 7 had very low means on the Interest scale and differed between themselves quite markedly on the Use scale, with Group 6 having a low mean compared with all the other boys' groups. Group 5 had only about average mean score on the Interest scale but came out highest on Use. On individual items they had a high mean on "I like a difficult problem in maths" (4.09), and they had the lowest means on "Maths worries me more than other subjects" (1.41) and "I find maths difficult" (1.77). Our expectation is that a substantial proportion of this group will go on to take physical sciences in the sixth form using mathematics as a supporting subject.

There remain Groups 1, 2, 3. Group 2 tended to be close to the overall mean except for having the highest score on the Teacher scale. Group 3 had the highest means on the items "I always try to do my best in maths" (4.64), "I could do better in maths if the teacher explained more clearly" (4.60), and "I'm often disappointed with my results in a maths test or exam" (4.12), so we get the impression that they were a conscientious group who would have liked to do better, the more so as their means were higher than those of Group 1 on "I often get

stuck in maths" (3.84, 2.40) and "I find maths difficult" (3.24, 2.66).

In concluding this section we observe that the three scales derived from the factor analysis (they are not factor scores) have proved useful in distinguishing between the groups obtained from the cluster analyses and it seems reasonable to us to suppose that they are not merely artifacts of the data but correspond to something in the real world. Before we pass on to the next section, it is of interest to observe that one item had the greatest discriminating power between groups (as measured by the statistic F) for both cluster analyses: this was "I find maths interesting".

Interviews

Interviews were conducted with 44 pupils in the autumn term at the beginning of their fourth year. The aim of this exercise was to delve more deeply into the question of pupils' feelings about mathematics.

Rather than making a random selection, the pupils interviewed were chosen both because they were likely to pass O level mathematics and also because they were extreme in some way. For example, those who particularly liked or disliked mathematics and those who scored highly on the AH4 test were interviewed. It was, pleasingly, very much harder to select pupils for interview who disliked mathematics than those who liked the subject; relatively few of those expected to pass O level had always disliked mathematics.

The interviews were analysed by dividing the interviewees into three groups - those who had always liked mathematics, those whose liking had increased over the years, and those whose liking had decreased.

(a) Pupils who had always liked mathematics

Members of this group displayed a long-standing ability in mathematics.

Their interest in mathematics was either also long-standing, or came with the introduction of new topics beyond basic mathematics at the beginning of secondary school. They had generally enjoyed mathematics most in their present school, with harder work and new topics being popular. Complaints tended to be about boredom when finishing work before the rest of the class, revision, repetition of work, and spending too long on a topic. On the whole this group felt they were benefitting from mathematics lessons.

(b) Pupils whose liking for mathematics had increased

Members of this group had mostly only started to like mathematics in their present school. Reasons for disliking mathematics previously revolved around the teacher and/or not understanding. The changes in attitude were due to a number of different factors. Some pupils found the work became easier when it was explained better in their present school, while others found the new topics harder, and so more challenging. Most of this group also felt they were benefitting from mathematics lessons.

(c) Pupils whose liking for mathematics had decreased

Most members of this group liked mathematics in their previous school, and were good at it then. The loss of interest came in the comprehensive school, with the introduction of new topics which the pupils found hard and/or irrelevant. Many of this group now find mathematics boring, perceiving it as "all the same, figures and that", and not particularly useful for the future. Few consider that they are benefitting from mathematics lessons now.

Interviews - comments

It is interesting to note that most pupils expected to pass O level mathematics could mention at least some stage in their school career when they had liked the subject, and many were able to mention one or more particularly good teachers.

One of the main impressions of the interviews is of the great change that occurs during the early years of the comprehensive school, when topics beyond basic mathematics are introduced. It seems to be at this point that interest in mathematics is renewed, created or destroyed. Some pupils view these topics as more interesting and more challenging, others find that matrices, translations, sets, algebra, etc. are too difficult, or feel they are of little benefit.

Another impression is that of mathematics being perceived as very varied by those who like the subject, or dull and lacking in variety by those who dislike it.

Conclusion

There is little doubt that the pupils generally viewed mathematics as a useful subject, as is shown by a mean score of over 4 on the Use scale. A sex difference on this scale has been noted, particularly on those items referring to personal use of mathematics. It is tempting to attribute this to social factors, as is commonly the case in discussions of the sex difference in the proportion of pupils specialising in mathematics. This may well be so below the surface level but girls disagreed more strongly than boys with the statement "Maths is a boys' subject" although there was little difference on "Physics is a boys' subject". We also noted sex differences on a number of items, several of which were inserted in the hope that they would help to predict choice of mathematics as an A level subject. There is some evidence from the Dislike/Like item and "I find maths interesting" that girls were enjoying their mathematics less than boys. Is there something intrinsic about the subject (e.g. its abstractness or impersonality), or is there something in the way it is taught (e.g. exercises with a bias towards boys' interests) that makes it appeal less to girls? Since girls had a higher mean score on the Teacher scale, the former seems more likely. So, while our evidence points towards less intrinsic interest in mathematics for girls, any attribution of cause would be speculative and we would not wish to deny the

existence of social pressures which encourage girls to drop mathematics.

Both girls' and boys' means on the Interest scale were more than one point below those on the Use scale. We can also compare responses to different subjects given by the pupils before they knew the project was primarily interested in mathematics. Asked to write down three subjects they thought they would like to study if they were to stay on into the sixth form or go to college after O level or CSE, more chose mathematics (38%) than any other subject, with English (30%) coming next. Nationally, and in Oxfordshire (OCC 1980), more people take English Literature than a mathematics A level but in the present five schools in 1979 it was the other way round. On a five point scale of Dislike (1) to Like (5), t-tests showed greater liking for PE and biology (mean differences with mathematics -0.21, -0.17) and less liking for chemistry, physics and French (mean differences 0.25, 0.40, 0.64); all these results are significant at the 1% level. Using a non-parametric ranking procedure (Backhouse et al 1980, 2.11) mathematics came sixth in order of liking out of twelve subjects. Seeing that mathematics is frequently a service subject (Backhouse 1979) in the sixth form, this is entirely consistent with it being the most frequently mentioned sixth form subject.

Within the educational system we can do little to make mathematics more useful except to help pupils to acquire a better grasp of the subject so that they are able to apply it. The intrinsic interest of the subject can be affected by the way it is taught but syllabuses are hard to change even if we were certain what would give pupils greater interest in the subject. According to the open ended responses we analysed, the overwhelming view of the pupils was that the best way to make the subject interesting is to help them to understand it. The quickest changes can be made through the teaching of the subject. Here the difficulty is that most teachers, like other people in all walks of life, tend to be conservative over the methods they use unless spurred on by some special

circumstances. We suggest that just such a crisis is here in the shortage of mathematics teachers and that the long term solution is to get more people interested in mathematics and specialising in it. H.M. Inspectors of Schools (1979, 136) have suggested that pupils are not always being as stimulated as they might be. We hope that observations made here and elsewhere (Kiryluk, 1980) may be helpful.

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Notes

(1) Factor analysis was carried out by the SPSS method PA2 with Varimax rotation. The first three factors accounted for 76% of the variance.

(2) The sampling unit for the project was the school. Accordingly two-way analyses of variance have been carried out to see whether pooling the pupils was justified. In no case was a statistically significant interaction found, and with one exception the probabilities were sufficiently close to those obtained by simpler methods for the latter to be presented, thereby simplifying the reporting. The analysis of variance was carried out by the BMDP program P2V.

(3) This item did not reach the 5% level of significance in the analysis of variance; there was a reversal of the means of the sexes in one rural school.

(4) Means on this item did not increase or decrease strictly with the points of the scale 2 (Difficult) to 5 (Very easy) for junior/middle school mathematics.

(5) Cluster analysis was carried out by means of Wishart's CLUSTAN1C using the k-means method. Pupils were assigned to 12 initial groups formed by the NAG random number generator and the analysis carried out three or four times with

different sets of random numbers. With both the boys' and the girls' samples, two of the runs yielded identical groups: the identical clusters were also those with the least error sum of squares.

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